

Determining Recovery Potential of Dredged Material for Beneficial Use – Site Characterization; Prescriptive Approach

PURPOSE: This technical note is one of three providing guidance on evaluating the potential for recovery of dredged material for beneficial use (BU), either as is or using physical separation (soil washing) to meet BU specifications. This technical note describes a prescriptive approach to estimating volumes meeting BU requirements. The prescriptive approach uses available information or information obtained from limited sampling to evaluate the feasibility of material reuse, available volumes, and the need for and feasibility of physical separation. The first technical note (Olin-Estes and Palermo 2000) introduces physical separation concepts and presents mathematical relationships for estimating material recovery potential (MRP). The third technical note in the series (Olin-Estes 2000) introduces statistical methods for developing a more extensive sampling plan and interpreting the resulting data.

BACKGROUND: The principal motivation for BU recovery of dredged material is the growing shortage of storage capacity in confined disposal facilities (CDFs). The fundamental purpose of these technical notes is to assist in determining when material recovery is technically and economically feasible, and provide a strategy for obtaining and using physical and chemical information necessary for this evaluation at the least possible cost. Olin-Estes and Palermo (2000) describe more fully the options existing to increase capacity, the fundamental approach to evaluating MRP, and physical separation concepts. This note and Olin-Estes (2000) address informational needs. The fundamental approach is to begin with available information and progress to targeted sampling and analysis as needed.

The feasibility of separation as a management approach is dependent on several factors: ability to identify distinct fractions within the material meeting BU criteria, ability to separate suitable fractions, and MRP as determined by available volumes of suitable material. This technical note introduces a prescriptive approach to data acquisition for feasibility evaluation and MRP estimation that is generally applicable, whether or not separation is required to meet BU specifications. Olin-Estes and Palermo (2000) and Olin-Estes (2000) introduce physical separation concepts and more rigorous statistical sampling and data estimation methods, respectively.

INTRODUCTION: If available information is inadequate to determine compatibility of material for identified local BU (Olin-Estes and Palermo 2000), at least limited sampling of the material will be needed to make a preliminary determination. Preliminary sampling and data acquisition compose the prescriptive site characterization described in this technical note. Figure 1 illustrates the place of prescriptive site characterization in the overall evaluation of feasibility for BU recovery.

DATA REQUIREMENTS: There are essentially two levels of MRP estimates: screening level, based on existing information, and definitive, based on more extensive site sampling. Several types of data are required to estimate MRP:

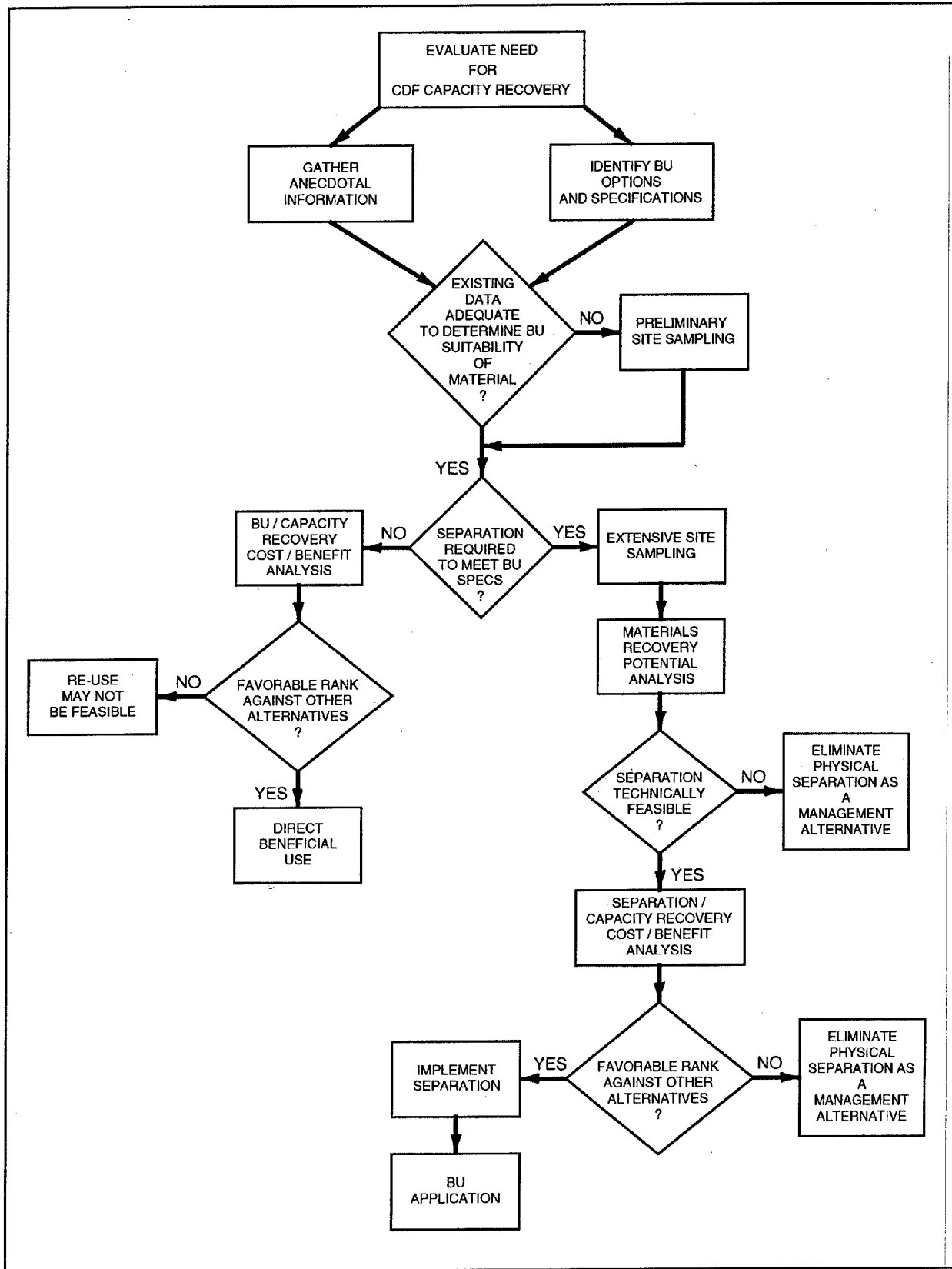


Figure 1. Evaluation of feasibility for BU recovery of dredged material

- Bulk sediment data:
 - Volume of available bulk sediment or dredged material.
 - Grain size distribution (GSD) of the bulk material (prior to separation).
 - Concentrations of contaminants of concern (COC) in the bulk sediments.
- Beneficial use specifications, including acceptable GSD and COC levels.
- Concentrations of COC in material fractions, if separation is determined to be necessary to meet BU specifications.

Project surveys and data from prior testing are the most likely sources of existing information. Although materials to be dredged or previously disposed in a CDF are typically characterized to some degree, both physically and chemically, this information was likely not obtained or structured with an eye toward evaluation of MRP and separation feasibility. Even so, percent sand and bulk contaminant levels are usually known, and can be useful for initial screening and MRP estimates, if the coarse material is assumed to be relatively clean. More targeted sampling and analysis will ultimately be required to obtain definitive information and to confirm this assumption.

While project data related to sediment physical and chemical characteristics as described previously are usually available for a number of stations in the case of in-channel evaluations, data are rarely available for in-CDF materials. Some idea of material properties in the CDF must be inferred from existing in-channel data, CDF site surveys and visual inspections of the CDF surface, and knowledge of CDF filling operations. In both in-channel and in-CDF locations, additional data should be obtained through sampling and testing if the initial screening evaluations indicate separation may be necessary and feasible. Olin-Estes (2000) describes approaches for designing a more extensive sampling plan and interpreting data. Olin-Estes and Palermo (2000) more fully describe BU specifications and COC considerations and provide mathematical relationships for using this information to calculate MRP.

In-Channel Evaluations. The following information is particularly important for site characterization of projects prior to dredging (materials in-channel):

- Shoaling rates and sediment volumes as a function of location and time within the waterway.
- Physical characteristics of the sediments in the waterway as a function of location and time, specifically the GSD of the sediments in situ.
- Contaminant distribution and magnitude for the sediments. Location of sources of contamination, such as industrial and sewage outfalls.

Hydrodynamics and the sources of sediments will govern the physical characteristics of the sediments in the waterway as a function of location and time. The target material from a waterway may be the total volume to be dredged for a given project or a portion of the total that can potentially meet the characteristics for BU, with or without separation. For example, past experience may indicate that sediments in certain reaches of a waterway or entrance channel tend to shoal with predominantly sandy sediments, while others shoal with fine-grained silts and clays. This information, when combined with volumes historically dredged from these reaches, gives an indication of the relative volumes of sandy versus fine material likely to be generated by a dredging event. Grain

size distribution data are normally available from past dredging evaluations. These data should be examined for every station sampled to determine which portions of the total shoal volume are potentially suited to BU, or may require separation to meet BU specifications.

In-CDF Initial Evaluations. The following information is particularly important for estimating reclamation potential of materials in an existing CDF:

- The area and likely thickness of material deposits in the CDF.
- Volumes, frequency, and rates of placement for materials in the CDF.
- Physical characteristics of the sediments in the CDF as a function of location and depth, specifically the GSD of the sediments in situ.
- Chemical characteristics of the COC as related to known sediment physical characteristics.

Some of this information may be inferred from knowledge of inflow and outflow points, disposal methods, and site operation and management practices. Material hydraulically placed in a CDF tends to separate to some degree due to the sedimentation process occurring within the site. Field data have provided information on the general behavior of dredged material in CDFs with respect to this particle sorting or separation. Several CDFs in the Great Lakes, each filled with predominantly fine-grained dredged material initially containing only a small fraction of sand, were evaluated in the 1970's. Grain size data indicated that all of the coarser sandy material settled in the CDF within a distance of 100 m from the inflow point. The grain size properties of the finer material were generally consistent in the larger portion of the CDF, with some clay-size material settling near the outflow weirs (Krizek 1976).

In general, for hydraulically filled CDFs, coarse-grained material (sand size and above) will tend to accumulate at the point of inflow. In fact, for many projects, the inflow pipes must be moved often to avoid buildup of high mounds of sandy material. The finer silts and clay also tend to separate to some degree, with a mixture of silts and clays spread from the mounded coarse material near the inflow area to near the outflow weirs. In some cases, finer clay fractions may accumulate in higher proportions toward the outflow points. The degree to which this occurs depends on the geometry of the CDF, the locations of inflow points and outflow weir structures, and operational factors such as the depth of ponding and flow rate during a particular filling operation.

Material distribution within a CDF may be more variable for mechanically dredged sediments than for hydraulically dredged sediments, depending upon the offloading method. Material is offloaded by mechanical means at many CDFs in the Great Lakes area. The material is typically offloaded from one or more points around the CDF. Mechanically dredged and offloaded material does flow, but will not exhibit significant particle size separation from settling.

Valuable information for a screening level evaluation can be obtained from a site visit and visual survey of conditions within the CDF, and a field inspection should always be conducted at this stage of evaluation. More information can be obtained if the CDF is easily accessible and the surface has been exposed to drying. Surficial samples will likely be helpful in the preliminary evaluation stage to determine surface material distribution by grain size in the CDF. Some chemical analysis

should also be done to obtain some indication of the types of contaminants present, and the contaminant levels of the bulk and separated material.

The operational history of the CDF and natural settling processes may be taken into account in developing a screening-level estimate of the MRP. It should be noted that any such estimate should take into account the three-dimensional aspect of the site. Figure 2 shows a CDF with multiple layers of material placed at intervals, each with its own mounded area of coarse material. Portions of the previous layer, which are fine-grained, may dry out and gain sufficient strength prior to the next filling operation to support sand mounds. Therefore, reliance on just a surficial delineation of the coarse-grained area may lead to errors in volume calculations. To avoid this, the relative percentages of coarse material in each filling event could be taken into account. Ultimately, core samples must be taken to verify distribution of material and refine recoverable volume estimates.

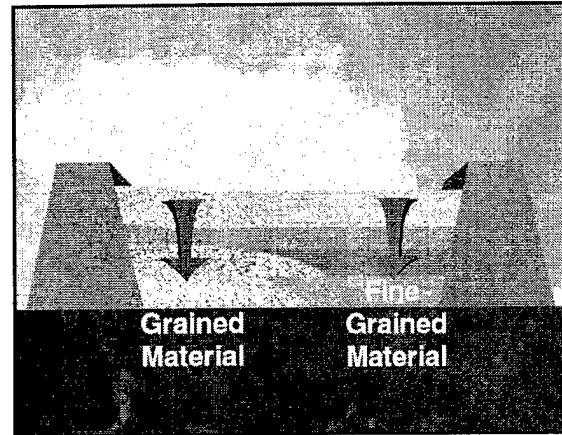


Figure 2. Typical layering of materials in hydraulically filled CDF

Results of Initial Evaluation. If existing data and surficial sampling are sufficient to determine BU suitability of the material and separation requirements, no further sampling is required. However, in many cases, GSD data available from tests run on in-channel materials or surficial samples will not be representative of the GSDs throughout the CDF. Additionally, fractionation testing to determine contaminant distribution is not generally done as a part of normal operating procedures. In most cases it is expected that a more detailed evaluation will be required to quantify and characterize the material. This will typically involve core sampling to the full depth of the deposit for CDFs. Two approaches can be taken for site sampling, depending on the scale and nature of the project: prescriptive, described in later sections of this technical note, or statistical, as described in Olin-Estes (2000).

GENERAL CONSIDERATIONS FOR ADDITIONAL SAMPLING: Guidance on site characterization for in-channel sediments is widely available (U.S. Environmental Protection Agency (USEPA)/U.S. Army Corps of Engineers (USACE) 1998), while such guidance for sampling material placed within a CDF is limited at present. A touchstone of all guidance presently available is the need for a written sampling and testing plan. Such a plan should be developed, reviewed, and approved by appropriate stakeholders prior to execution. Guidance on sampling plan development is available (USEPA/USACE 1998; Headquarters, USACE, 1994; Olin-Estes 2000).

The sampling strategy or plan must be developed to characterize either the entire site (in-channel or in-CDF) or portions of the site with potential for material recovery. The number and location of samples should be the minimum required to adequately characterize the materials and allow a reliable estimate of MRP. Prescriptive evaluations rely on a limited number of samples applied to selected areas, based on the existing data and knowledge of the behavior of the materials and management of the site. Statistical approaches determine sample numbers and locations based on the variability of material properties. In general, statistical approaches will require a higher number

of samples than prescriptive approaches, but have the advantage of facilitating statistical analysis of data obtained and providing established methods to extrapolate data to unsampled areas.

It may be possible to coordinate a single sampling effort to meet a number of project needs; the design of the sampling program for MRP should be closely coordinated with other sampling requirements to avoid duplication and reduce costs. Other sampling and testing requirements, for example, the evaluation of other sediment treatment approaches such as bioremediation or manufactured soil, could be conducted jointly with an evaluation of BU and separation feasibility.

Extensive guidance on sampling methods and equipment is available (Mudroch and MacKnight 1991). The approaches would differ, however, for in-channel versus in-CDF sampling programs. The testing requirements will influence the type and volume of sample as well as the sample handling and preservation requirements. For evaluating BU and separation feasibility, determination of material grain size, bulk sediment chemistry (with respect to COC), and associated fractionation of COCs with grain size or density ranges are the normal objectives of testing. Sample volume requirements and analyte selection are further discussed in following sections.

PRESCRIPTIVE GUIDANCE ON SITE CHARACTERIZATION: The prescriptive approach to sampling and testing determines an appropriate number of samples and selection of sampling locations based on sound judgment, considering project conditions and regulatory requirements. Past testing and characterization data, anecdotal evidence such as knowledge of shoaling and sedimentation patterns in waterways, or prior experience with behavior of materials placed in CDFs serves as the basis of such an initial evaluation. The numbers of samples using the prescriptive approach would likely be much lower than those indicated by statistical approaches described in Olin-Estes (2000). Guidance on in-channel site characterization is widely available (USEPA/USACE 1998) and is applicable in the context of evaluating MRP. Depending on the BU options under consideration, a sampling effort for MRP can be focused on specific areas within a waterway or within a CDF to obtain the most information for the least effort and cost. Targeted sampling is possible only when information on the distribution of material properties within the overall site is available. However, there are considerations that should be emphasized for selection of the optimum sampling locations and numbers of samples.

Sampling Locations. Sample locations can be selected using a uniform (grid) approach or a clustered approach, with the clusters concentrated on areas of interest. If the initial evaluation of existing data provides some indication of areas within the waterway or CDF with higher potential for material recovery, a clustered approach will save resources and provide a better definition of material characteristics for those areas with higher recovery potential. Areas with low potential can either be not sampled or sampled with a very low resolution to confirm the existing data and historical record. Selection of sampling locations within CDFs should be guided by known behavior of materials hydraulically or mechanically placed in the CDF. The fact that coarser material tends to accumulate adjacent to the inflow points for hydraulically placed sediments can be used to cluster locations toward specific areas within the site, assuming recovery of coarse materials is likely the objective.

Spacing. The spacing between stations will be governed by the variability of the material within the site, the overall size of the areas to be sampled, and total number of stations deemed affordable, considering the scale of the project and funding constraints.

Depth of Sampling. The depth to which in-channel material should be characterized should extend to the full depth of anticipated dredging. Multiple samples at depth at a given location would not be required to provide vertical resolution if the dredging depth will be only a few feet (say less than 3 ft (0.9 m)) and the material appears to be relatively homogeneous throughout this depth. For maintenance projects, previous data may indicate if vertical differences in sediment composition are evident even with greater shoal thickness. For new work, or for cases where maintenance dredging has not taken place in many years, some sampling at depth will be required to define vertical resolution.

Depth of sampling within a CDF is dependent on the lift thickness, as estimated using the area of the CDF and the volumes placed in each specific filling operation. As shown in Figure 2, the three-dimensional layering pattern formed by natural separation of coarse and fine material may influence the depths at which samples are taken, and the depth of sampling could be different for different areas within the CDF. Sampling at depth within a CDF will normally be accomplished with core samples.

Sample Replication and Sample Compositing. Other than standard quality assurance/quality control (QA/QC) (USEPA/USACE 1995), sample replication is generally not a regulatory requirement for characterization data, either physical or chemical. However, taking multiple samples for analysis from a homogenized sample increases the reliability of the data. This concept is further described in the following section, "Sample Size Required." Samples taken from different locations on the site are not generally composited, unless the material will be blended for processing. Even in this eventuality, it may be more valuable initially to analyze samples individually to better define overall site variability. Sections of sample cores, however, will be composited and a small sample taken from some or all of these intervals for chemical analysis. Determination of appropriate compositing intervals is an important element of the testing strategy. Pre-screening based on visual inspection of grain size, color, and odor may facilitate this determination. Once individual characterization samples are tested, the results can then be used to select a scheme for compositing samples for further testing as a cost-savings measure. In addition, some statistical sampling approaches use sample compositing, as described in Olin-Estes (2000).

Sample Size Required. Sample size refers to the volume of material that is homogenized and then sampled for analysis. For example, if a 1.8-m (6-ft) core is taken, it will normally be subdivided into smaller sections, which are thoroughly homogenized; and then a very small subsample of each homogenized section is taken for chemical analysis. Because sediments and the distribution of contaminants within the sediments are typically very heterogeneous, homogenization volume is a relatively important factor in obtaining data that is representative of site conditions. The greater the volume being homogenized, the more difficult it is to mix the sample adequately to produce a truly uniform sample. However, the more heterogeneous a material is, the larger the homogenization volume required to capture randomly distributed components. Figures 3 and 4, adapted from Bourbie, Coussy, and Zinszner (1987), illustrate this concept for the measurement of acoustic properties of porous media. The chief difference is that measurement of macroscopic mechanical

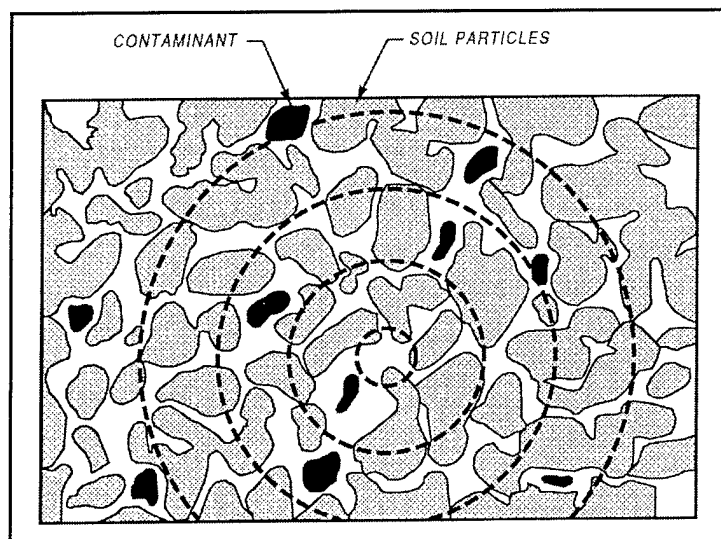


Figure 3. Effect of increasing sample size in capturing scattered soil inclusions (adapted from Bourbie, Coussy, and Zinszner 1987)

many inclusions, but will be difficult to homogenize to uniformity; the results may be more reflective of the averaging that occurs with material blending, and fail to provide information regarding the overall range of variation of the component of interest. Again, the fact that only a small fraction of the homogenized volume is actually used for chemical analysis emphasizes the value of taking multiple samples from each homogenization volume in defining variability. As indicated in Figure 4, some properties of porous media approach an asymptotic value at a given volume. This concept should be applicable to estimation of properties that can be measured using most or all of the homogenized sample, but the application to contaminant analysis is dubious because only a small fraction of the sample is analyzed.

Physical Testing. Physical testing of all samples should be conducted prior to any chemical fractionation testing, since the physical tests are fast and inexpensive, will yield data that may rule out separation as a necessary or viable approach, and indicate which samples should undergo chemical analysis. Chemical fractionation testing should be conducted only when separation appears to be necessary to meet BU requirements, physical data suggest that BU specifications could be met with separation, and separation appears to be technically feasible. The physical data may also lead to strategies for compositing samples for the contaminant

properties takes advantage of the entire homogenization volume, while measurement of contaminant concentrations or physicochemical properties uses only a very small fraction of the selected homogenization volume. Figure 3 is a conceptual drawing of a porous medium with the solid particles (gray), pore spaces (white), and inclusions of some type (black). By analogy, one can picture the inclusions as contaminated sediment particles mixed in with clean particles, and the effect of increasing volume in capturing a representative number of these inclusions in each homogenization volume. A volume that is too small may not capture any inclusions. One that is too large will capture

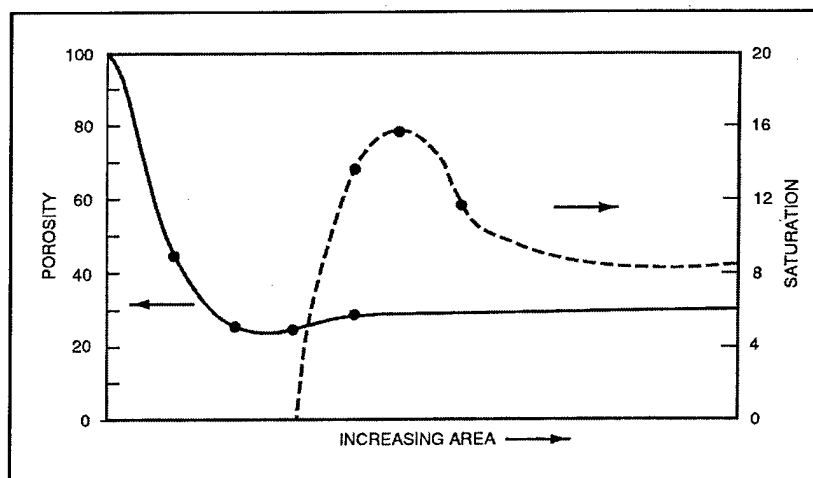


Figure 4. Asymptotic behavior of porous media characteristics with increasing sample size (adapted from Bourbie, Coussy, and Zinszner 1987)

distribution (fractionation) testing. Several testing methods are described in Olin-Estes and Palermo (2000).

Chemical Analysis. Selection of analytes for chemical analysis is a key component of the feasibility evaluation, and will significantly impact the overall cost of the site characterization. Ultimately, this is a regulatory issue. For the purposes of preliminary site characterization, some cost savings can be achieved by limiting the number of analytes where possible. This may be done by doing a full suite of metals and organic compounds on a few bulk samples likely to represent the worst-case contamination. Compounds not detected in the bulk analysis can be eliminated from most of the fractionation testing, although a full suite should be done on all fractions of some samples as confirmation. Sample volume required to conduct a full suite analysis on each fraction is discussed in more detail in Olin-Estes and Palermo (2000).

COMPLETION OF BU/SEPARATION FEASIBILITY EVALUATION: Once a reliable estimate of MRP has been developed using the procedure outlined in Olin-Estes and Palermo (2000), the information can be used in completing the evaluation of BU/separation feasibility. If recovery potential matches the requirements for the BU applications under consideration, and separation is required, selection of appropriate operational methods or equipment for separation and a cost analysis can be performed and the final decision on separation feasibility made. Procedures for equipment selection and cost estimating are described in Olin et al. (1999).

CONCLUSIONS: Development of a re-use plan for a CDF or dredging project will require a multistep approach incorporating existing data, practical and/or statistical sampling approaches, and identification of local BU opportunities and requirements. Little field verification is presently available regarding the efficacy of one sampling approach over another in characterizing the distribution of materials in a CDF. As further field experience is gained, refinements can likely be made that will result in an optimal approach and greater confidence in the results. Physical separation is only one of several approaches that can be taken to produce material suitable for various beneficial uses, and should be evaluated together with other alternatives to determine the most suitable approach for a given site.

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REFERENCES

- Bourbie, T., Coussy, O., and Zinszner, B. (1987). *Acoustics of porous media*. Editions Technip, Paris.
- Headquarters, U.S. Army Corps of Engineers. (1994). "Requirements for the preparation of sampling and analysis plans," Engineer Manual 200-1-3, Washington, DC. <http://www.usace.army.mil/inet/usace-docs/eng-manuals/em.htm>
- Krizek, R. J. (1976). "Spatial nonhomogeneity of dredged materials in confined disposal areas." *1976 Proceedings of WODCON VII*, San Francisco, CA.
- Mudroch, A., and MacKnight, S. D. (1991). *CRC Handbook of techniques for aquatic sediment sampling*. CRC Press, Boca Raton, FL.
- Olin, T. J., Bailey, S. E., Mann, M. A., Lutes, C. C., Seward, C. A., and Singer, C. F. (1999). "Physical separation (soil washing) equipment for volume reduction of contaminated soils and sediments," EPA-905-R99-006, Assessment and Remediation of Contaminated Sediments Program, Great Lakes National Program Office, Chicago, IL.
- Olin-Estes, T. J. (2000). "Determining recovery potential of dredged material for beneficial use – Site characterization: Statistical approach," *DOER Technical Notes Collection* (ERDC TN-DOER-C15), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer
- Olin-Estes, T. J., and Palermo, M. R. (2000). "Determining recovery potential of dredged material for beneficial use – Soil separation concepts," *DOER Technical Notes Collection* (ERDC TN-DOER-C13), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer
- U.S. Environmental Protection Agency/U.S. Army Corps of Engineers. (1995). "QA/QC guidance for sampling and analysis of sediments, water, and tissues for dredged material evaluations - Chemical evaluations," EPA-823-B-95-001, U.S. Environmental Protection Agency, Washington, DC.
- U.S. Environmental Protection Agency/U.S. Army Corps of Engineers. (1998). "Evaluation of dredged material proposed for discharge in waters of the U.S. -Testing manual (The inland testing manual)," EPA-823-B-98-004, U.S. Environmental Protection Agency, Washington, DC. <http://www.epa.gov/ostwater/itm/index.html>

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